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A REVIEW OF SABLEFISH POPULATION STRUCTURE IN THE NORTHEAST PACIFIC OCEAN AND IMPLICATIONS FOR CANADIAN SEAMOUNT FISHERIES

Context

On the west coast of Canada, many commercial fish populations are delineated into separate "stocks" for some combination of biological and operational reasons. For example, biological attributes of a fish population may suggest genotypic and/or phenotypic differentiation from other populations of the same species in nearby areas. Management practice may separate a population into stocks because of constraints to area-specific monitoring of catch and discards, enforcement, and assessment. Requirements for population-specific analysis of biological, catch, and abundance data typically dictate stock separation from a larger population. Finally, fish populations that straddle national boundaries, or exist in whole or part within international waters, can be delineated into stocks purely for policy reasons.

Canadian Sablefish (*Anoplopoma fimbria*) fisheries at seamounts located within and outside of the Pacific Canadian Exclusive Economic Zone are managed independently of Sablefish fisheries along the continental shelf and slope of British Columbia. While the total allowable catch for the coastal fishery is determined annually via quantitative analysis of coastal fishery catch and abundance data, Sablefish harvests from seamount populations are regulated by monthly vessel limits and input control tactics involving limited entry licensing, seasonal closures, and gear restrictions. Emergence of this distinct form of harvest management for seamounts was not based on biological evidence of stock structure differences between seamount Sablefish and coastal populations. Rather, differences arose from the contrasting origins of these fisheries; coastal fisheries grew into large-scale industrial operations in the 1970s, while seamount fisheries developed from experimental activities in the 1980s.

Fisheries and Oceans Canada's Pacific Region Ecosystem Management Branch and Fisheries and Aquaculture Management Branch requested Pacific Region Science Branch to provide science information and advice to assist evaluation of fishery compliance with the Sustainable Fisheries Framework policy and to support development of management plans for the Sgaan Kinghlas - Bowie Seamount Marine Protected Area (SK-B MPA). Sablefish fishing by longline trap gear is permitted within Zone 2 of the SK-B MPA by the Bowie Seamount Marine Protected Area Regulations. Specifically three questions were posed:

1. Do Sablefish located at seamounts and the continental shelf and slope of coastal British Columbia represent different biological populations?
2. What is the nature [e.g., frequency and magnitude] of Sablefish exchange between seamount and coastal populations? and
3. What are the benefits and risks of alternative approaches to managing seamount and coastal Sablefish as a single stock?

This paper reviews life history, genetic, and tag release-recovery studies throughout the Sablefish range in the northeast Pacific Ocean and presents previously unpublished tag release-recovery data to determine the degree of empirical support for biologically distinct Sablefish populations on seamounts and in coastal areas. Following synthesis of this information, a summary of three alternative options for management of seamount Sablefish in

Canada

British Columbia is provided; however detailed evaluation of their relative efficacy requires knowledge of the complete range of objectives for seamount ecosystems. Some objectives are only indirectly related to the status of Sablefish, such as those pertaining to habitat and species diversity, but may impose constraints on Sablefish harvest.

This Science Response Report results from the Science Special Response Process of May 30, 2013 on A Review of Sablefish Population Structure in the Northeast Pacific Ocean and Implications for Canadian Seamount Fisheries. There has been no past advice provided on this issue, and at this time there is no expectation of further advice on Sablefish population structure.

Background

Sablefish (a.k.a., Blackcod) inhabit shelf and slope waters throughout the North Pacific Ocean from the Aleutian Islands and Bering Sea to Baja California. Within this range, Sablefish also tolerate relatively low oxygen concentrations, which allow this species to occupy the entire slope region to depths greater than 1500 m. Age, size, and maturity vary among areas and depths (Saunders et al. 1997, Sigler et al. 1997). Growth is rapid; individual Sablefish reach 55 cm fork length in about 3 to 5 years with maximum lengths to about 110 cm. The oldest reported Sablefish age from BC waters is 92 years. Annual coastwide Sablefish production is usually dependent on low to moderate recruitment punctuated with occasional large year classes that may persist for periods of 8-10 years. Sablefish become vulnerable to trawl, longline trap and longline hook fisheries at ages 3 to 5.

The total allowable catch (TAC) of coastal (non-seamounts) Sablefish is set annually in proportion to estimated total available production (Cox et al. 2011). The TAC for the coast is allocated between the directed longline trap and longline hook K license category sectors (91.25%) and the trawl T license category sector (8.75%); both fishery sectors utilize an individual transferable quota system to allocate their portion of the TAC among individual harvesters (DFO 2013). Sablefish captured incidentally by longline hook fisheries directed at Pacific halibut, rockfishes, lingcod, spiny dogfish, and other demersal species must be accounted for within the limits of the TAC. Individual quota or vessel limits are monitored in both coastal and seamount fisheries via 100% at-sea video or observer coverage with independent auditing and fishery-independent dockside validation of landings. Total annual landings for 2012 (2,175 t) are near the lowest levels since 1969 (Figure 1).

A 55 cm fork length minimum size limit regulation applies to all Canadian commercial Sablefish fisheries. All Sablefish traps must be equipped with at least two escape rings with an inside diameter of at least 8.89 cm (3.5 inches) to reduce capture of undersize fish, and trap mesh must include rot panels to mitigate against ghost fishing by lost traps. The size limit does not apply to the recreational fishery where a daily bag limit of four (4) Sablefish is in effect. Research, assessment, management, and enforcement activities undertaken by Fisheries and Oceans Canada (DFO) have been augmented by a collaborative agreement with the Sablefish industry K license holders.

In contrast to coastal fisheries, annual harvests from seamount Sablefish populations are regulated via a combination of input and output control measures (DFO 2013). First, only one vessel per month is allowed to fish seamounts between April and September, inclusive, for each of the northern and southern seamount fisheries. Only longline trap gear can be fished in the northern seamount fishery, while both longline hook and trap gear can be fished in the southern seamount fishery. Trawl gear is not permitted for seamount fisheries. Sablefish catch by each vessel is restricted to a monthly limit of 75,000 lbs (34 mt) that can be taken from each seamount fishery. On average, seamount fishing accounts for about 3% (range 0.4% to 8%) of

total Canadian Sablefish landings and Bowie Seamount, in particular, has accounted for the majority of all seamount landings (Figure 1).

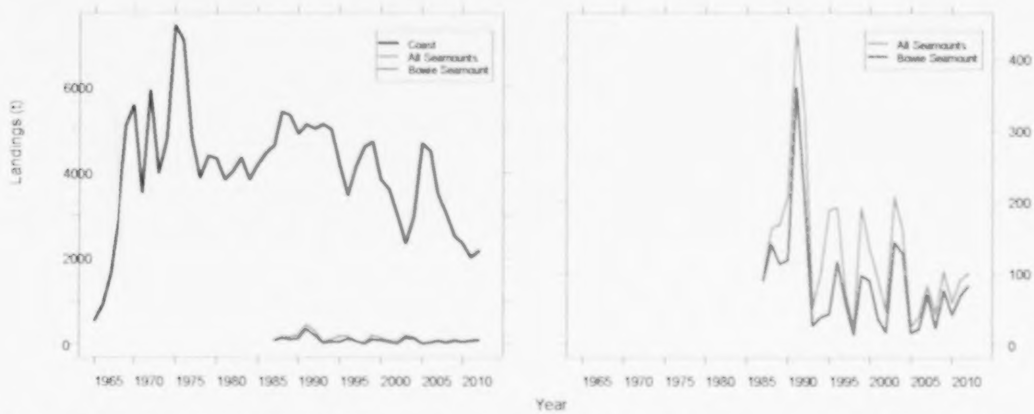

Figure 1. Sablefish landings from 1965 to 2012 in coastal B.C. waters, all seamounts, and Bowie Seamount (left panel). Landings from Bowie Seamount account for the largest proportion of total seamount landings (right panel). Data were obtained from the GFCatch, PacHarvSable, and FOS databases maintained by Fisheries and Oceans Canada, Pacific Region.

Analysis and Response

The prevailing population structure hypothesis for north Pacific Sablefish – as originally suggested by tag release-recovery studies (Kimura et al. 1998) – is that two populations potentially exist along the coast of North America. One population is thought to extend northwest from northern Vancouver Island through the Gulf of Alaska, Aleutian Islands, and the Bering Sea. The second population is believed to extend south from northern Vancouver Island to Baja California. Recent genetic analyses failed to detect genotypic differentiation in support of the two-population hypothesis; only weak differentiation was found between the northern and southern extremes of the Sablefish range (Tripp-Valdez et al. 2012). The lack of apparent biological population structure probably arises because Sablefish are highly mobile at all spatial scales relevant to their life history. As larvae and juveniles, Sablefish are transported by surface currents at scales of 10-100 km; as sub-adults, Sablefish make ontogenetic movements from shallow to deep waters over 100s of kms; and adult Sablefish may make ocean-basin scale movements up to 1000s of kms. Therefore, mixing of members from the putative populations is likely sufficient for Sablefish to be considered one biological population. Life history characteristics, tag release-recovery analyses, genetic studies, and other information supporting this conclusion are reviewed below, followed by a synthesis of management implications and potential alternative management options.

Early life history

Sablefish spawning occurs between January and May at 300-500 m depths near the edge of the continental shelf, with later spawning occurring at higher latitudes (Mason et al. 1983, Kendall and Materese 1987, McFarlane and Nagata 1988, Sigler et al. 2001). Eggs are pelagic and may incubate for several weeks, sinking to depths between 400-1000 m prior to hatch as individual egg density increases (Kendall and Matarese 1987). Yolked larvae feed at depth but move immediately toward the surface layer where they are advected by ocean currents. Larvae have been captured as far offshore as 160 km in southeast Alaska (Wing 1997), to 240 km in the Aleutians, up to 370 km elsewhere (Kendall and Matarese 1987), and greater than 180 km

off the BC coast seaward of spawning areas (Mason et al. 1983). There is no clear transition from rapidly growing larvae to young-of-the-year (YOY) juveniles, but growth of the larval stage from 7 to 40 mm was estimated to take about 12 weeks (Boehlert and Yoklavich 1985). Both larva and YOY stages are thought to be obligate surface dwellers as they drift shoreward (McFarlane and Beamish 1983, Kendall and Materese 1987). Typically, by the end of summer, YOY less than 200 mm reach nearshore and inlet waters where they remain over winter reaching 300-400 mm by the following summer. At this time, juveniles (400-600 mm) begin offshore movement to deeper water with younger fish (about ages 3-4) inhabiting the continental shelf and older fish migrating to the slope habitat (Rutecki and Varosi 1997a,b, Saunders et al. 1997). Sablefish in the Gulf of Alaska, and at least some proportion of fish from northern BC, tend to move counter-clockwise through the Gulf of Alaska reaching adult habitat within 4 to 5 years (Maloney and Sigler 2008, Rutecki and Varosi 1997b, Heifetz and Fujioka 1991). Small (<57 cm fork length) Sablefish tagged in Chatham Sound in south eastern Alaska tended to move north and westward while larger fish (>66 cm fork length) tended to move south and eastward (Maloney and Heifetz 1997).

Coastal tag releases and recoveries

Tag release-recovery studies carried out by Canadian and US agencies since the late 1970s show that Sablefish travel long distances throughout their range, including between all regions of the coast and seamounts. Beamish and McFarlane (1988) reported that adult Sablefish tagged in BC waters were primarily (>75%) recovered within 50 km of the release site, except for fish tagged along the west coast of Haida Gwaii (formerly Queen Charlotte Islands). Between 12% and 21% of tagged Sablefish were recovered more than 200 km from their release site, and the chance of being recaptured at greater than 200 km increased further with longer times at liberty (Beamish and McFarlane 1988). Recent release-recovery data (1991-2012) are consistent with Beamish and McFarlane (1988) where about 40-50% of Sablefish are still recovered within 50 km of the release site (Table 1). In general, the proportion of tags recovered declines with distance from release site for a given time at liberty. The proportion of recoveries increases with time at liberty for distances greater than about 500 km from the release site. Note that these distances (great circle distance) do not reflect the actual distance travelled because only the release and recovery locations are known.

Recoveries of Sablefish tagged and released in the northeast Pacific show: (1) **inshore-offshore** movement from mainland inlets to outer coastal waters, (2) **along-shore** exchange of fish among offshore coastal areas, (3) **coastal-seamount** movement of fish from mainland inlet and coastal release sites to seamounts off the BC coast (Figure 2), (4) **regional-scale** movement from BC to US waters, and from US waters to BC (Figure 3), and (5) **ocean basin-scale** movement from BC waters to the Aleutians, Bering Sea, and south to Baja California. The least observed movement behaviour is from coastal BC or US waters to inshore areas and inlets where juvenile Sablefish are generally located.

Table 1. Sablefish tag recoveries (%) by distance from release site and years at liberty for all BC releases between 1991 and 2012. Distances were determined using the great circle distance between the survey release location and reported fishing logbook recovery location.

	Distance (km) from Release Location							
Years at Liberty	**<10**	**11-50**	**51-100**	**101-250**	**251-500**	**501-1000**	**1000+**	**Recoveries**
1	31.5	22.8	10.1	21.2	8.2	3.2	2.9	**22,371**
2-5	23.8	17.8	8.2	25.7	12.2	4.6	7.8	**27,358**
6-10	23.9	17.6	8.0	20.4	12.6	7.3	10.3	**6,031**
11+	25.0	19.1	8.2	16.2	12.4	8.6	10.5	**1,105**
Total	**15,278**	**11,228**	**5,091**	**13,177**	**6,066**	**2,500**	**3,525**	**56,865**

The timing and spatial distribution of Sablefish tag recoveries in US waters led Kimura et al. (1998) to conclude that northern and southern populations exist within the North American range. Fish tagged and released in Alaska and northern BC showed reciprocal migration to all other Alaskan and northern BC areas, in agreement with Figure 3, but were found less frequently in more southern areas. For instance, about 3.5% of Alaska fish were estimated to migrate south to the west coast and about 4.4% of fish from the west coast to Alaskan waters. Tagged fish were rarely recovered as far south as California. In the south, fish tagged and released off Washington, Oregon and California were typically recovered only within the area of release (Kimura et al. 1998). Sablefish tagged from Alaska to California were also recovered at seamounts (Kimura et al. 1998, Shaw and Parks 1997), demonstrating that Sablefish migrate from coastal areas across the abyssal plain to seamounts.

Seamount tag releases and recoveries

Sablefish captured by bottom trawl were tagged and released at Bowie and Union Seamounts during February 1987 (Murie et al. 1995). These two release groups are the only recorded tagging events at seamounts in BC waters with the exception of new work underway at Bowie Seamount in April 2013. Tagged fish ranged in size from 310-890 mm fork length at time-of-tagging. Fish from these releases were recovered at the seamount of release, as well as coastal BC and Alaska (Table 2), demonstrating that Sablefish also move from Canadian seamounts to coastal areas. Similar movements were observed for tag releases from Gulf of Alaska seamounts (Maloney 2004). For example, of 3,337 Sablefish released on eight seamounts from 1999 to 2002, 42 fish were recovered on the seamount of release, none have been recovered on seamounts other than the seamount of release, and 17 have been recovered on the continental slope. In contrast, a small release of 99 tagged Sablefish on five Gulf of Alaska seamounts in 1979 resulted in five fish being recovered on the seamount of release and none elsewhere.

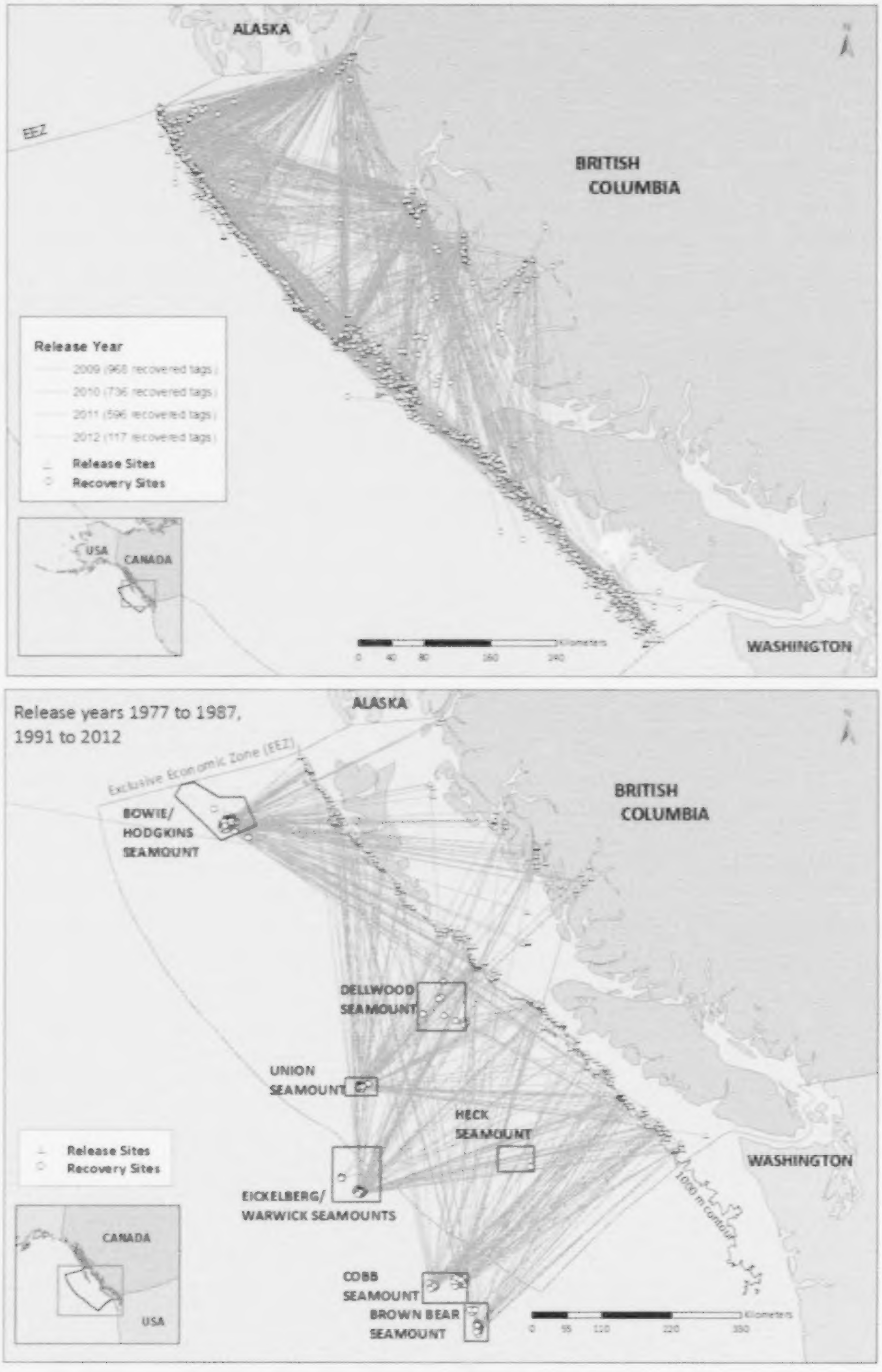

Figure 2. Recoveries of tagged Sablefish in BC waters from BC releases. Recovery locations (circles) of Sablefish released from 2009 to 2012 (triangles) are shown in the upper panel. Seamount recoveries (circles) for Sablefish tagged and released in BC (triangles) from 1977-1987 and 1991-2012 are shown in the lower panel. Data were extracted from the FishTag database maintained by Fisheries and Oceans Canada, Pacific Region.

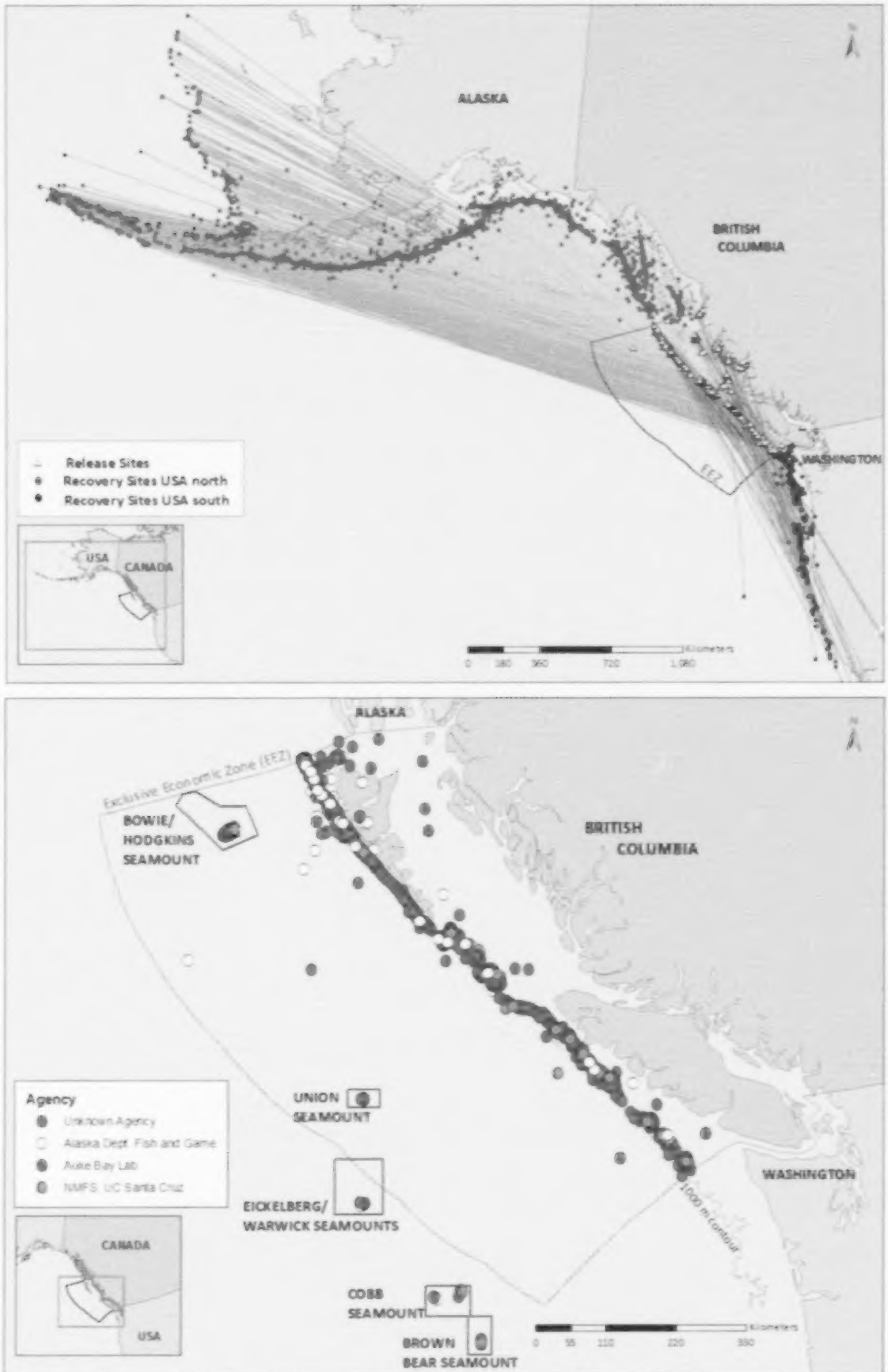

Figure 3. Recovery locations (circles) in US waters of Sablefish tagged and released in BC (triangles) between 1991 and 2012 (upper panel). The lower panel shows all BC coastal and seamount recovery locations for Sablefish tagged in US waters by release agency. Release locations are not available for fish tagged by US agencies. Data were extracted from the FishTag database maintained by Fisheries and Oceans Canada, Pacific Region.

Table 2. Tag recoveries by area and year from the 1987 Bowie and Union Seamount tag releases. Years with no recoveries are not shown, and there have been no recoveries since 2007.

Release Location	**Recovery Area**	**Recovery Year**															
		87	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**00**	**01**	**05**	**07**	**Total**
Bowie Seamount (*n*=299)	Bowie Seamount	5	10	2			1										**18**
	North Coast			2	2	2											**6**
	Alaska		1	1	1						1	1					**5**
	Foreign Vessel														1	1	**2**
	Unknown					1				2	1						**4**
	Total	**5**	**11**	**5**	**3**	**3**	**1**	**0**	**0**	**2**	**2**	**1**	**0**	**0**	**1**	**1**	**35**
Union Seamount (*n*=317)	Union Seamount			6		1	1	1									**9**
	South Coast	1	6	4	2									1			**14**
	QCS												1				**1**
	Foreign Vessel					1											**1**
	Unknown		1					1	1	1							**4**
	Total	**1**	**7**	**10**	**2**	**2**	**1**	**2**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**29**

As of 1994, more than 150 Sablefish tagged in Alaska coastal and continental slope waters had been recovered on seamounts off the coasts of BC and Washington State, but only seven on Gulf of Alaska seamounts (Maloney 2004). This difference was attributed to relatively greater fishing effort at BC and Washington seamounts.

Of the 130 Sablefish tagged in Alaskan coastal waters and recovered on Bowie Seamount, approximately 50%, 22%, and 10% were released in the eastern, central, and western Gulf of Alaska, 8% were released off the Aleutian Islands, and 11.5% were from the Bering Sea. Although these tagging studies clearly demonstrate that Sablefish move relatively freely along the west coast of North America, as well as between coastal areas and remote seamounts (Alton 1986; Shaw and Parks 1997, Table 1, Table 2, Figure 2, Figure 3), several key uncertainties regarding movement dynamics remain.

Productivity of seamount Sablefish populations is highly uncertain, but probably low. Although Sablefish have been observed in spawning condition at seamounts, there is a lack of evidence for actual reproduction and recruitment. For instance, of the 440 Sablefish ages determined from Gulf of Alaska seamount samples, only 7 were younger than age-6 and none were younger than age-4. Consequently, Maloney (2004) concluded that Sablefish at seamounts in the northeast Pacific are likely sustained by immigration of maturing or adult fish from coastal populations. Maloney (2004) speculated that Alaskan Sablefish might utilize the eastward flowing North Pacific Current off the Aleutian Islands and western Gulf of Alaska until encountering a seamount. Returns of fish from seamounts to coastal waters could be via the northward flowing Alaska Current.

Although it seems clear that seamount Sablefish populations readily mix with coastal stocks, the absolute rate of exchange between coastal areas and seamounts, as well as exchange among seamounts, is unknown because tag releases at seamounts have been small and haphazard

over time. Similar reasons also explain our lack of understanding about Sablefish residency time at seamounts and habitat associations while resident.

The potential of tag release-recovery data to detect evidence of population structure could be increased by application of tags to spawning adults; tags in BC are typically applied in October and November during the annual research survey (Wyeth et al. 2007), whereas spawning likely occurs in late winter and early spring depending on latitude. For example, if Sablefish tended to exhibit spawning site fidelity and data shown in Figure 2 and Figure 3 were restricted to releases and recoveries during spawning periods, then distances between release and recovery might be appear shorter, regardless of the actual distance traveled. Figure 4 shows tagging data recoveries in February through April only; the patterns of trajectories are similar to those for the unrestricted data. Only data from April would be relevant for seamounts, since seamount fisheries are closed from October through March. There are no recoveries of fish in April from the 1987 Bowie and Seamount releases (Table 2).

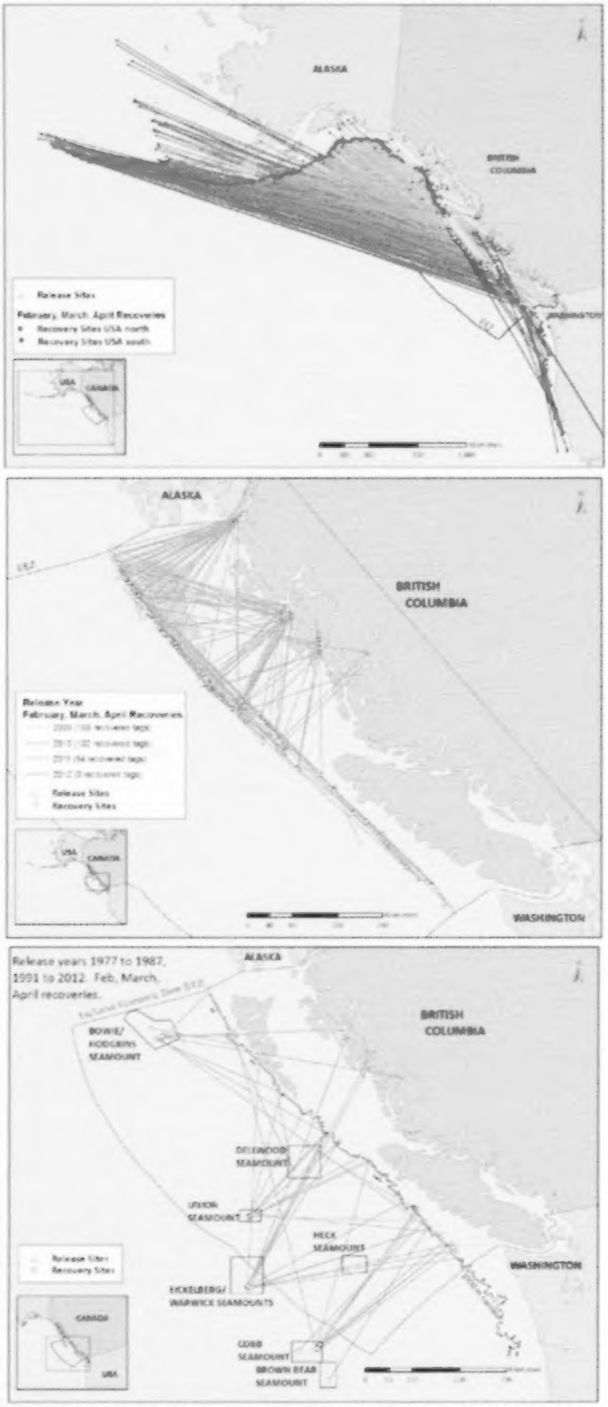

Figure 4. February through April recoveries of Sablefish tagged in BC waters for US waters (upper panel) and BC waters (centre and lower panels). Recovery locations are shown as circles and release locations in BC as triangles. Sablefish in US waters and those in coastal BC were recovered between 1991 and 2012. Seamount recoveries (lower panel) include the periods from 1977-1987 and 1991-2012. Data were extracted from the FishTag database maintained by Fisheries and Oceans Canada, Pacific Region

Otolith microchemistry

One study of Sablefish found differences in otolith microchemistry from samples of juveniles taken from three regions along the Washington and Oregon coasts which suggested fish were feeding at different trophic levels (Gao et al. 2004). Although the authors concluded that Sablefish exhibit some population structuring, and therefore do not represent a single biological population, we believe that their study is inconclusive because it did not indicate whether the observed differences were stable over time or whether they merely reflected diet differences in juvenile Sablefish reared in different areas. Differences in otolith microchemistry can only suggest differences in habitat use among individual fish. Movement of adults to new spawning areas, which homogenizes the genetic makeup of the overall population, was not detectable from these microchemistry observations. However, to date genetic differences between Sablefish in Washington and Oregon waters have not been detected.

Genetic structure

Two early studies of genetic structure in Sablefish used allozymes as a means to distinguish groups (Tsuyuki and Roberts 1969; Gharrett et al. 1982). Tsuyuki and Roberts (1969) sampled 25 locations from Alaska to Oregon, including 11 British Columbia locations at Dixon Entrance, Graham Island, four sites around Haida Gwaii, Goose Island, Smith Sound, and two sites along the west coast of Vancouver Island. Gene frequencies for four allozymes did not differ between any of these locations. The lack of evidence for population structure was attributed to the wide ranging migrations observed in tagging studies (Tsuyuki and Roberts 1969).

In contrast, Gharret et al. (1982), using 13 allozymes, observed greater genetic heterogeneity in allele frequencies between locations than within locations. Samples were taken from California to the end of the Aleutian chain, including fish from five seamounts in the Gulf of Alaska, which were combined into one group. The degree of heterogeneity was greater in samples taken from the center of the species range, suggesting some large-scale population structuring but with higher mixing of populations in the center of the range. Similar allele frequencies between sampling locations indicated that large population sizes or migration had reduced differences among groups (Gharrett et al. 1982). No locations were identified for putative population boundaries.

Finally, a recent study of Sablefish population structure using four microsatellite loci and one mitochondrial locus detected weak genetic structure between northern populations sampled from the Bering Sea and Gulf of Alaska, and a southern population sampled near San Quintin, Mexico (Tripp-Valdez et al. 2012). The fixation index, F_{ST}, is a measure of the amount of inbreeding that occurs within a group or population compared to other groups or populations. Because inbreeding is related to population size, marine fishes, which typically have large populations (i.e., millions of individuals), have very low F_{ST} values (i.e., $F_{ST} = 0.02$, Ward et al. 1994). Despite these low values, significant restrictions in gene flow, sufficient to result in the independent demographic response of populations, can be detected using the F_{ST} statistic (Hastings 1993, Hauser and Carvalho 2008). Tripp-Valdez et al. (2012), after applying a correction for the presence of null alleles, found an F_{ST} of 0.0141 between San Quintin and the Bering Sea and 0.0100 between San Quintin and the Gulf of Alaska. However, neither sample was significantly different from an intermediate sample from Oregon waters. This result suggests potential genetic isolation by distance, wherein geographically distant populations appear different while geographically proximate populations appear similar. The notion of distance in this context depends, in part, on how far fish migrate, which is considerable for Sablefish, and the degree of connectivity between potential populations. Although Tripp-Valdez et al. (2012) show that two Sablefish populations are more likely than 1, 3, or more, based on the allele frequencies of the markers used in the study, there was not enough statistical power

to discriminate fish among populations or the approximate geographic boundaries. Analyses of mtDNA also did not reveal population differentiation because the locus had a large diversity of genotypes arising from relatively low sequence divergence. The observed difference between genotypes was due to a 1 or 2 base pair change, which is indicative of rapid expansion in population size (Tripp-Valdez et al. 2012). Unfortunately, such changes reveal little about population structure. Tripp-Valdez et al. (2012) concluded that Sablefish from the Bering Sea, Gulf of Alaska and Oregon form the same biological population. Sablefish off the coast of Canada are within that geographic range and would therefore be assumed to be part of that population.

However, it should be noted that none of these studies sampled spawning groups, and the number and type of molecular markers employed may not have had the statistical power to distinguish subtle genetic structure. Therefore, opportunities to conduct additional investigation into the genetic population structure of Sablefish should strive to collect samples during spawning times and include adult fish rather than juveniles to minimize bias due to non-random sampling of families (Waples 1998; Gao et al. 2004).

Morphometrics

Morphometric differences among Sablefish sampled from Alaska, Oregon and Mexico are statistically significant, although the magnitude of these differences were small and probably not biologically significant (Tripp-Valdez et al. 2012). Also, Sablefish growth patterns appear to differ by spatial location and depth within an area probably because Sablefish tend to move deeper with maturation, which may itself be size-dependent. Therefore, larger fish of a given age are more likely to be mature and deeper than a smaller fish of the same age (Saunders et al. 1997, Sigler et al. 1997).

Parasite assemblages

Sablefish collected in 1985 showed a different prevalence of parasitic fauna (Trematoda) for fish caught at Cobb and Union Seamounts (Kabata et al. 1988) compared to fish caught at locations on the BC continental slope between 1983 and 1985. Although Kabata et al. (1988) concluded that seamount and coastal Sablefish represent separate and distinct stocks, differences in parasite prevalence between coastal sampling locations were also described. Prevalence of parasites was very low in Sablefish less than three years old, consistent with earlier findings that Sablefish acquire trematodes after the end of their second year of life (Kabata and Whitaker 1984).

Additional samples were collected in 1987 from Dellwood and Bowie Seamounts, and in 1988 from Bowie and Union Seamounts (Whitaker and McFarlane 1997). Differences in prevalence between seamounts were observed for some trematode parasites, however, only the 1988 Bowie and Union Seamount samples were collected during the same month of the year. Seasonal variation in prevalence was noted for some trematodes found in Sablefish (Whitaker and McFarlane1997). Based on their analysis of parasite prevalance, Whitaker and McFarlane (1997) concluded that individual seamounts represent distinct stocks. However, they also concluded that immigration of fish age 3 and older was a major source of recruitment to seamount populations.

Unfortunately there has been no opportunity to confirm that observed differences in the prevalence of parasites has persisted over time. For example, fish samples from Union Seamount in 1984 were infected by *Fellodistomum breve*, *Lecithochirium exodicum*, and *Derogenes varicus* (Kataba et al. 1988) while fish sampled in 1988 from Union Seamount were infected by the trematodes *F. breve* and *L. exodicum*, but also by *Podocotyle atomon*, *Genolinea laticauda*, and *G. japonica* (Whitaker and McFarlance 1997) Thus, differences in

prevalence could arise because coastal and seamounts Sablefish have exposure to parasite species in their diet that differ not only by location but also over time. Given results from tag release-recovery data that show immigration of Sablefish to seamounts from throughout the northeast Pacific (Shaw and Parks 1997, Kimura et al. 1988, Figure 2, Figure 3) it is possible that transitory differences could arise at seamount populations as a function of the relative mixing of parasite infected fish from different coastal locations.

Management considerations

Coastal BC Sablefish are primarily managed using annual TACs that are implemented via individual transferable quotas and a comprehensive fishery monitoring system. An annual fishery-independent survey program produces biological and abundance indexing data for quantitative stock assessment modelling of coastal Sablefish population dynamics (Wyeth et al. 2007). Such information is central to the coastal Sablefish management procedure that is tuned to achieve specified stock and fishery objectives (Cox et al. 2011, DFO 2013). The same approach has not been used for seamount Sablefish because of the separate evolution of this fishery and a lack of directed research on assessment methods and management procedures for seamount fisheries. Developing these assessments mainly involves challenges that relate to data: (1) fishery-independent abundance indices for seamount populations are not available, and (2) low sampling intensity by commercial fisheries may be inadequate to establish reliable long-term trends in abundance for most seamount populations. Nevertheless, the seamount fisheries currently have several elements of precautionary management such as monthly vessel limits and restrictions on vessel entry, closed seasons, and a size limit. Two escape rings to minimize capture of sub-legal fish are also mandatory on all traps fished at seamounts. Additionally, there are credible independent, at-sea estimates of catch for all species via observers and electronic monitoring (at-sea cameras), as well as high quality landings data via fishery-independent 100% dockside validation. Thus, research on specific methods to assess and manage sustainable fisheries at seamounts could be based on high quality catch data, but may face challenges for indices of abundance.

There are two compelling reasons for not including seamount Sablefish abundance and catch data in the assessment and management of coastal fisheries to set a single TAC for Sablefish. First, there is a substantial mismatch in the scale of harvest control; scale mismatch in harvest control systems may weaken management ability to detect undesirable fish population states and responses to management actions. Second, objectives for seamount habitat and biodiversity are different than those for coastal areas; unlike seamounts, coastal areas are imbued with a complex suite of objectives related to the prosecution of a large scale groundfish fishery.

Management of Sablefish along the Canadian and US coasts occurs at a very large spatial scale that is matched to the size of the areas. Each nation's management system implements negative feedback controls that couple estimates of stock status with decision rules that adjust harvest, thus, TACs are adjusted reasonably quickly in response to estimated changes in stock status. Harvest activities for seamount populations occur at much smaller scales than for coastal areas – scales that may be as small as the individual seamounts themselves. Including seamount populations within the larger coastal area could result in a management system where changes are applied to seamount catches in the absence of any feedback about the state of those populations.

The effects of propagating assessment errors applicable to coastal stocks would also be relatively more severe at the level of individual seamounts. For instance, biomass estimation errors of several thousand tonnes are relatively inconsequential to the coastal population, but could result in a substantial change in exploitation rates of seamount Sablefish. Although there is strong evidence for Sablefish exchange between seamounts and coastal populations, it is not

clear whether such exchange keeps the population fluctuations in phase with each other. If the populations are not in phase, then higher absolute magnitude of catch errors associated with higher coastal biomass could cause disproportionate increases in exploitation rates of seamount Sablefish, even when seamount Sablefish biomass is low or declining. Only in the rare case in which the population fluctuations are exactly in phase would coastal biomass estimation errors have inconsequential effects on seamount Sablefish exploitation.

A choice to manage BC Sablefish as a single coastal-seamounts unit also implies that the desired trade-off between conservation and yield objectives are the same for coastal and seamount populations. This is likely not the case because seamount habitats are subject to policy considerations unrelated to the management of Sablefish harvest. For example, Regulation (3) pertaining to the SK-B MPA states there should be no activity that causes disturbance, damage, destruction or removal of any living marine organism or any part of its habitat. However, Regulation (4a) states commercial fishing that is carried out in accordance with the Fisheries Act and its regulations is an exception to Regulation (3). Regulation (3) at the SK-B MPA does not apply to the coastal fishery and necessarily creates potential for a different trade-off of fishery and habitat outcomes than is desired for the coastal fishery. Such special designation of seamount habitat (or compliance with international agreements for seamount habitat management) means that ecosystem considerations for seamounts differ from the coastal fishery management area. From a socio-economic perspective, the Sablefish fishery in coastal waters must meet constraints imposed by the more complex, multi-gear/multi-species integrated groundfish fishery, which is irrelevant to Canadian seamounts.

Alternative management procedures

Alternative options for seamount Sablefish fishery management procedures may include (1) status quo management, (2) coastal assessment with proportional allocation of catch to seamounts, or (3) seamount-specific assessment and harvest management via a hierarchical approach. It is important to note here that detailed evaluation of alternative management approaches for seamount fisheries requires knowledge of the full range of constraints (e.g., habitat or biodiversity objectives) applicable to seamount fisheries. In concert with the need to formulate a full suite of objectives, new analytical methods are required to evaluate options 2 and 3, and both options imply an increased level of management control relative to the current system. A brief prospectus for each alternative option is provided below; however, the results of a quantitative and policy evaluation might suggest a hybrid of the tactics described or alternative options.

1. **Status quo management**. No change to management for BC seamount Sablefish results in the situation where the coastal population is under negative feedback control via pre-determined objectives, reference points and decision rules, but the seamounts rely on existing input and output controls with no consensus on objectives for the populations, fishery, seamount habitat, or other species. Although we have not evaluated seamount fisheries explicitly, the current assumption is that negative feedback control for the seamount populations could occur via inverse relationships between profitability and fishing effort as indicated by the number and duration of trips relative to limited entry and monthly vessel limits, respectively. In other words, harvests would be assumed to be reduced or curtailed as a fishery response to input and output controls, low catch rates and insufficient profit margins. However there is no direct local feedback control at the scale of individual seamounts under this approach since (1) northern and southern seamounts are grouped into two areas for management purposes, (2) there are no fishery-independent population abundance data, and (3) there is a lack of reliable long-term fishery-based abundance data for many individual seamounts.

2. **Coastal Assessment with Proportional Allocation of Catch**. Sablefish in BC could be assessed as one management unit with spatial allocation of the TAC to coastal and seamount

populations. Allocation of TAC to seamounts could be determined in proportion to recent seamount total catch relative to the coastal area, and then allocated among seamounts in proportion to seamount-specific catches. Under this option, reference points, assessment, and decisions rules would apply to Sablefish in BC, not to individual seamounts. Provided other objectives could be met, operational control points to limit fishing at individual seamounts could be chosen based on existing time series of commercial logbook data (following the seamount assessment research suggested above) only for those few seamounts that have a relatively regular history of fishing. Limit control points based on fishing history would curtail fishing when catch rates are low and allow population increases to greater densities before resumption of commercial fishing. Decision rules would be needed to (1) restart fishing after breaching a limit or after simply not occupying a given seamount, and (2) curtail fishing to meet constraints imposed by habitat considerations, the interception of non-target species, or other constraints. Higher Sablefish population density may increase catch rates, profitability and, in turn, reduce the amount of gear contact with benthic habitat required to achieve a given catch. However, under this scheme the overall seamount TAC is determined using only abundance information derived from the coastal population with no fishery-independent population abundance data for seamounts to provide direct feedback control. Thus, the mismatching scale of harvest control is not eliminated.

3. **Seamount-specific assessment and harvest management via a hierarchical approach**. Extending option (2) to incorporate seamount-specific feedback control could be done via a hierarchical approach in which seamount-specific assessments are conducted for Sablefish standing stock and net biomass flux (immigration – emigration). A hierarchical assessment approach would create sharing of certain information (e.g., immigration rate per hectare, emigration rate, fishery catchability) among seamount assessments, thus improving precision and stability of key assessment quantities. Such assessments might not be ideal compared to typical coastal analyses, but coupling harvest to local biomass and trends could overcome the mismatching scale of control presented by option (2).

Conclusions

Population structure

The majority of empirical evidence suggests sufficient movement and exchange of Sablefish to form a single biological population throughout their known range in the northeast Pacific Ocean (Table 3). High mobility of Sablefish at almost all life history stages along with tag release-recovery suggests there is little impediment to spatial exchange and genetic analysis show only relatively minor support for genetic differentiation at very large spatial scales (e.g., Baja California versus Aleutian Islands; Table 3). Based on associations with latitude and bathymetry, Sablefish are the most widely distributed commercial groundfish in the north Pacific (Moser et al. 1994). At least one ontogenetic stage can be found in virtually every habitat ranging from larvae in the neustonic layer (upper most surface layer of the ocean < 1 m), pelagic and benthic juvenile stages in fjords and inlets, and adult stages along the continental shelf and slope to 1500 m depth. Juvenile Sablefish (~30 cm fork length) have also been captured in the pelagic zone at considerable distances from the coast (Mason et al. 1983, Brodeur and Pearcy 1986). Oceanic transport of neustonic larvae and long distance directed movement of juvenile and adult Sablefish are probably important drivers of their widespread distribution, although pathways of movement remain uncertain.

Exchange between coastal and seamount populations

There is clear evidence for exchange of Sablefish between seamounts and other parts of their range in the northeast Pacific. Sablefish in the Gulf of Alaska may utilize the North Pacific

Current to move from coastal waters in the Gulf of Alaska to seamounts, but other seamounts may be reached by swimming directly from the coast (e.g., Bowie Seamount). The relative rates of exchange between coastal and seamount populations, as well as among seamount populations, are unknown at this time.

Management considerations

The conclusion that seamount Sablefish abundance is largely driven by net exchange with coastal Sablefish confounds, at least initially, applicability of the Fishery Decision-Making Framework Incorporating the Precautionary Approach, which requires reference points, harvest decision rules, and acknowledgement of uncertainty in implementing the decision rules. Without a closed-population stock-recruitment assumption, the status level at which serious harm occurs (i.e., B_{LIM}) is obscure. On the contrary, there is evidence that rescue effects from coastal populations are substantial enough that irreversible harm is highly unlikely even at extremely low seamount Sablefish abundance.

Evaluation of the relative performance of alternative seamount Sablefish fishery management procedures outlined here requires knowledge of the full range of habitat, biodiversity, and/or policy objectives applicable to seamount fisheries, such as those related to international agreements for seamount management or marine protected area designation. Choosing between alternative management procedures requires establishing the hierarchical ordering of the objectives so that a satisfactory trade-off of outcomes related to conservation, habitat, biodiversity and fishery yield outcomes can be identified. Research on specific methods to assess and manage a seamount fishery would benefit from high quality catch data, but may be challenged by the lack of reliable indices of abundance. Methods that would help to overcome the potential problem of scale mismatch of control may be costly to develop, but may be needed depending on the desired trade-off of outcomes for seamount habitats and sablefish.

Table 3. Summary of factors related to Sablefish stock structure.

Factor	Summary	References
Early Life History	Protracted egg and mobile larva stages with wide seaward distribution, larva occur in neuston layer in relatively fast moving surface waters with YOY juveniles inshore. Thus highly mobile early life history stages due to onshore-offshore transport, alongshore movement, and active inshore migration at juvenile stage to inlets. Strong evidence for large scale mixing of eggs, mobile larva, and juveniles with movement from distant offshore to inshore and inlet habitats.	Mason et al. (1983) McFarlane and Beamish (1983) Kendall and Matarese 1987
Tagging	Tag release-recovery from the northeast Pacific shows (1) **inshore-offshore** movement from mainland inlets to outer coastal waters, (2) **along-shore** exchange of fish among offshore coastal areas, (3) **coastal-seamount** movement of fish from mainland inlet and coastal release sites to seamounts off the BC coast, (4) **regional-scale** movement from BC to US waters, and from US waters to BC, and (5) **ocean basin-scale** movement from BC waters to the Aleutians, Bering Sea, and south to Baja California. Strong evidence for transport and movement of all stages throughout species range suggests a single biological stock.	Beamish and McFarlane (1988) Kimura et al. (1998) Maloney (2004) Shaw and Parks (1997) Figure 2, Figure 3
Genetics	Allozyme studies either showed no evidence for population structure along the northeastern Pacific coast or found weak evidence that some structure may exist. Microsatellite studies found evidence for structure only at an ocean-basin scale between northern populations sampled from the Bering Sea and Gulf of Alaska, and a southern population sampled near San Quintin, Mexico. No evidence of genetic population structure found within BC.	Tsuyuki and Roberts (1969) Gharrett et al. (1982) Tripp-Valdez et al. (2012)
Microchemistry	Differences in otolith microchemistry for juveniles found corresponding to trophic shifts in groups along the coast. Differences potentially indicate population structuring, but lack of temporal consistency and confounding with differences among rearing areas limit inferences. These results do not indicate whether the observed differences are stable over time or whether they reflected diet differences in juvenile Sablefish reared in different areas. Inconclusive evidence of biological stock structure.	Gao et al. (2004)
Morphometrics	Statistical differences in morphometrics significant but subtle differences may not be biologically meaningful. Sablefish are a difficult to age species and exhibit highly variable size at age by depth and spatial location within putative populations. Inconclusive evidence of biological stock structure.	Tripp-Valdez et al. (2012) Saunders et al. (1997) Sigler et al. (1997)
Parasites	Unique parasitic fauna observed in seamount fish but no evidence that differences with coastal populations are stable over time or a function of seamount residency, i.e., the parasites are acquired at immigration. Inconclusive evidence of biological stock structure.	Kabata et al. (1988) Whitaker and McFarlane (1997)

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Sources of Information

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Alton, M.S. 1986. Fish and crab populations of Gulf of Alaska seamounts. *In* R. N. Uchida, S. Hayasi, and G. W. Boehlert (editors), Environment and resources of seamounts in the North Pacific, U.S. Dep. Commerce, NOAA Tech. Rep. NMFS 43. p. 45–51

Beamish, R.J. and McFarlane, G.A. 1988. Resident and dispersal behavior of adult sablefish (*Anoplopoma fimbria*) in the slope waters off Canada's west-coast. Can. J. Fish. Aquat. Sci. 45: 152-164.

Boehlert, G.W. and Yoklavich, M.M. 1985. Larval and juvenile growth of sablefish, *Anoplopoma fimbria*, as determined from otolith increments. Fish. Bull. 83(3): 475-481.

Brodeur, R.D. and Pearcy, W.D. 1986. Distribution and relative abundance of pelagic nonsalmonid nekton off Oregon and Washington, 197P-84. US. Dep. Commerce, NOAA Tech. Rep. NMFS 46, 85 pp

Cox, S.P., Kronlund, A.R., and Lacko, L. 2011. Management procedures for the multi-gear sablefish (*Anoplopoma fimbria*) fishery in British Columbia, Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/063. viii + 140 p.

DFO. 2013. Pacific Region Integrated Fisheries Management Plan: Groundfish. Effective February 21, 2013, Version 1.1. Fisheries and Oceans Canada.

Gao, Y.W., Joner, S.H., Svec, R.A., and Weinberg K.L. 2004. Stable isotopic comparison in otoliths of juvenile sablefish (*Anoplopoma fimbria*) from waters off the Washington and Oregon coast. Fisheries Research 68, 351-360.

Gharrett, A.J., Thomason, M.A., and Wishard L.N. 1982. Biochemical genetics of sablefish. NWAFC Report 82-5.

Hastings, A. 1993. Complex interactions between dispersal and dynamics: lessons from coupled logistic equations. Ecology. 74: 1362-1372.

Hauser, L. and Carvalho, G.R. 2008. Paradigm shifts in marine fisheries genetics: ugly hypotheses slain by beautiful facts. Fish Fisheries. 9: 333-362.

Heifetz, J. and Fujioka, J.T. 1991. Movement dynamics of tagged sablefish in the northeastern Pacific Ocean. Fish. Res. 11:355-374.

Kabata, Z. and Whitaker, D.J. 1984. Results of three investigations of the parasite fauna of several marine fishes of British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1303.

Kabata, Z., McFarlane, G.A., and Whitaker, D.J. 1988. Trematoda of sablefish, *Anoplopoma fimbria* (Pallas, 1811), as possible biological tags for stock identification. Can. J. Zool. 66: 195-200.

Kendall, A.W. and Matarese, A.C. 1987. Biology of eggs, larvae, and epipelagic juveniles of sablefish, *Anoplopoma fimbria*, in relation to their potential use in management. Mar. Fish. Rev. 49 (1): 1-13.

Kimura, D.K., Shimada, A.M., and Shaw, F.R. 1998. Stock structure and movements of tagged sablefish, *Anoplopoma fimbria* in offshore northeastern Pacific waters and the effects of El Nino-southern oscillation on migration and growth. Fish. Bull. 96: 462-481.

McFarlane, G.A. and Beamish, R.J. 1983. Preliminary observations on the juvenile biology of sablefish (*Anoplopoma fimbria*) in waters off the west coast of Canada. In Proceedings of the International Sablefish Symposium. Alaska Sea Grant Report 83-8. p. 119-134.

McFarlane, G.A. and Nagata, W.D. 1988. Overview of sablefish mariculture and its potential for industry. Proceedings of the Fourth Alaska Aquaculture Conference, Alaska Sea Grant Report 88-4. p. 105-120.

Maloney, N.E. 2004. Sablefish, *Anoplopoma fimbria*, populations on Gulf of Alaska seamounts. Mar. Fish. Rev. 66(3): 1-12.

Maloney, N.E. and Heifetz, J. 1997. Movements of tagged sablefish, *Anoplopoma fimbria*, released in the eastern Gulf of Alaska. *In* M.E. Wilkins and M.W. Saunders (editors). Biology and Management of Sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130. p. 115-130.

Maloney, N.E. and Sigler, M.F. 2008. Age-specific movement patterns of sablefish (*Anoplopoma fimbria*) in Alaska. Fish. Bull. 106: 305-316.

Mason, J.C., Beamish, R.J. and McFarlane, G.A. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (*Anoplopoma fimbria*) off the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 40: 2126-2134.

Moser, G.H., Chakter, R.L., Smith, P.E., Lo, N.C.H., and Ambrose, D.A. 1994. Early life history of sablefish, *Anoplopoma fimbria*, off Washington, Oregon, and California, with application to biomass estimation. CalCOFI Rep., Vol. 35: 144-159.

Murie, D.J., Mitton, M., Saunders, M.W., and McFarlane, G.A. 1995. A summary of sablefish tagging and biological studies conducted during 1982-198 by the Pacific Biological Station. Can. Data Rep. Fish. Aquat. Sci. 959: 84p.

Rutecki, T.L. and Varosi, E.R. 1997a. Distribution, age, and growth of juvenile sablefish, *Anoplopoma fimbria*, in Southeast Alaska. *In* M.E. Wilkins and M.W. Saunders (editors). Biology and Management of Sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130. p. 45-54.

Rutecki, T.L. and Varosi, E.R. 1997b. Migrations of juvenile sablefish, *Anoplopoma fimbria*, in Southeast Alaska. *In* M.E. Wilkins and M.W. Saunders (editors), Biology and Management of Sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130. p. 123-130.

Saunders, M.W., Leaman, B.M., and McFarlane, G.A. 1997. Influence of ontogeny and fishing mortality on the interpretation of sablefish, *Anoplopoma fimbria*, life history. *In* M. E. Wilkins and M. W. Saunders (editors), Biology and Management of Sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130. p. 81-92.

Shaw, F.R. and N.B. Parks. 1997. Movement patterns of tagged sablefish, *Anoplopoma fimbria*, recovered on seamounts in the northeast Pacific Ocean and Gulf of Alaska. *In* M. E. Wilkins and M. W. Saunders (editors), Biology and Management of Sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130. p. 151-158.

Sigler, M.F., Lowe, S.A., and Krastelle, C.R. 1997. Age and depth differences in the age-length relationship of sablefish, *Anoplopoma fimbria*, in the Gulf of Alaska. *In* M. E. Wilkins and M. W. Saunders (editors), Biology and Management of Sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130. p. 55-63.

Sigler, M.F., Rutecki, T.L., Courtney, D.L., Karinen, J.F. and Yang, M.-S. 2001. Young-of-the-year sablefish abundance, growth, and diet. Alaska Fish. Res. Bull. 8(1): 57-70.

Tripp-Valdez, M.A., Garcia-de-Leon, F.J., Espinosa-Perez, H., and Ruiz-Campos, G. 2012. Population structure of sablefish *Anoplopoma fimbria* using genetic variability and geometric morphometric analysis. J. Applied Ichthy. 28: 516-523.

Tsuyuki, H. and Roberts, E. 1969. Muscle protein polymorphism of sablefish from the Eastern Pacific Ocean. Fish. Res. Brd. Can. 26, 2633-2641.

Waples, R.S. 1998. Separating the wheat from the chaff: patterns of genetic differentiation in high gene flow species. J. Heredity 89, 438-450.

Ward, R.D., Woodwark, M., and Skibinski, D.O.F. 1994. A comparison of genetic diversity levels in marine, freshwater, and anadromous fishes. J. Fish Bio. 44: 213-232.

Whitaker, D.J. and McFarlane, G.A. 1997. Identification of sablefish, *Anoplopoma fimbria* (Pallas, 1811), stocks from seamounts off the Canadian Pacific coast using parasites as biological tags. *In* M. E. Wilkins and M. W. Saunders (editors), Biology and Management of Sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130. p. 131-136.

Wing, B.L. 1997. Distribution of sablefish, *Anoplopoma fimbria*, larvae in the Eastern Gulf of Alaska. *In* M. Saunders and M. Wilkins (eds.). *In* M. E. Wilkins and M. W. Saunders (editors), Biology and Management of Sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130. p. 13-26.

Wyeth, M.R., Kronlund, A.R, and Elfert, M. 2007. Summary of the 2005 British Columbia sablefish (*Anoplopoma fimbria*) research and assessment survey. Can. Tech. Rep. Fish. Aquat. Sci. 2694. 105p.

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